

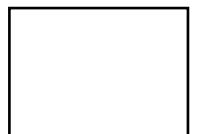
**KECK**

# **KECK INTERFEROMETER**

## **Keck Interferometer Description and Performance**

Mark Colavita

9/19/97



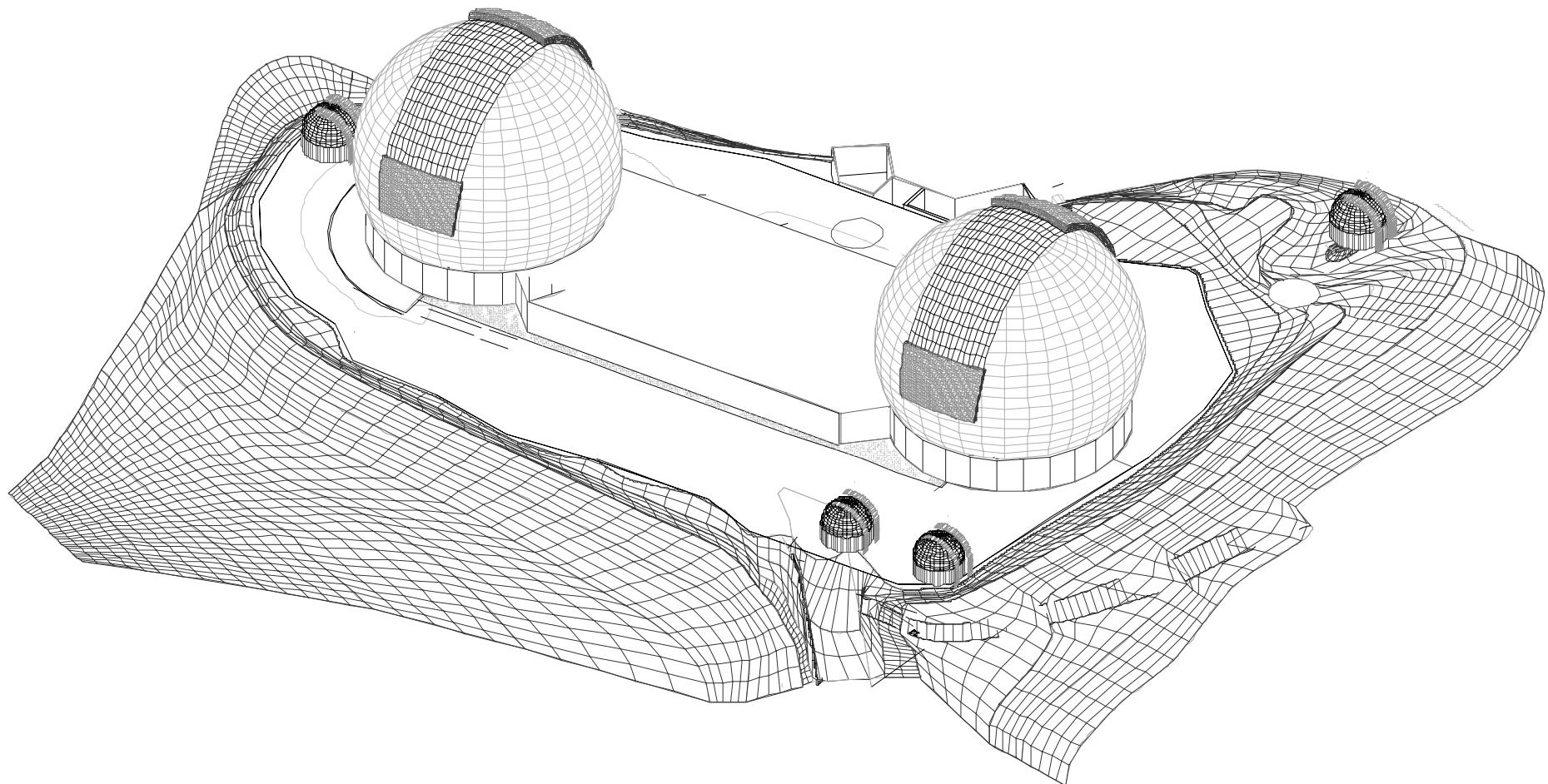
# KECK INTERFEROMETER

## System Description

- Michelson interferometry between two Kecks and 4 outrigger telescopes
  - Phasing with adaptive optics and fast tip/tilt correction
  - Cophasing with fringe detection/tracking and fast delay lines
  - Laser metrology to monitor optical path for vibration control and precision astrometry and cophasing
  - Different modes for different science objectives; vary in
    - » Number of telescopes
    - » Type of combination: pair-wise, multi-way, nulling
    - » Science wavelength
    - » Cophasing source
      - Science star at short wavelength
      - Separate object in field (“off-axis”)

# KECK INTERFEROMETER

**Aerial View Looking West**



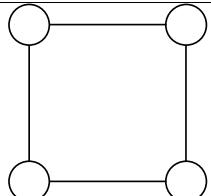
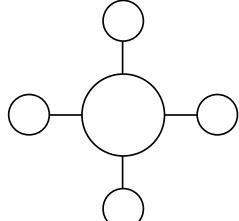
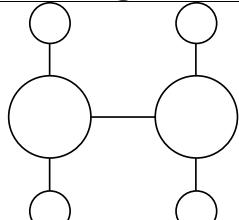
# KECK INTERFEROMETER

## Functional Requirements

- Support 4 fundamental science observing modes
  - Exozodi detection with nulling
  - Two-color phase-difference planet detection
  - 6-way imaging
  - Astrometry
- Key design drivers
  - Phasing and cophasing architecture
  - Flexibility to accommodate multiple modes
  - Nulling to detect 10 solar-system equivalent zodi
  - Cophasing to  $K = 13$
  - Astrometry to 20 uas
  - Astrometric sensitivity to  $K = 17$
  - Imaging sensitivity to  $K = 20$

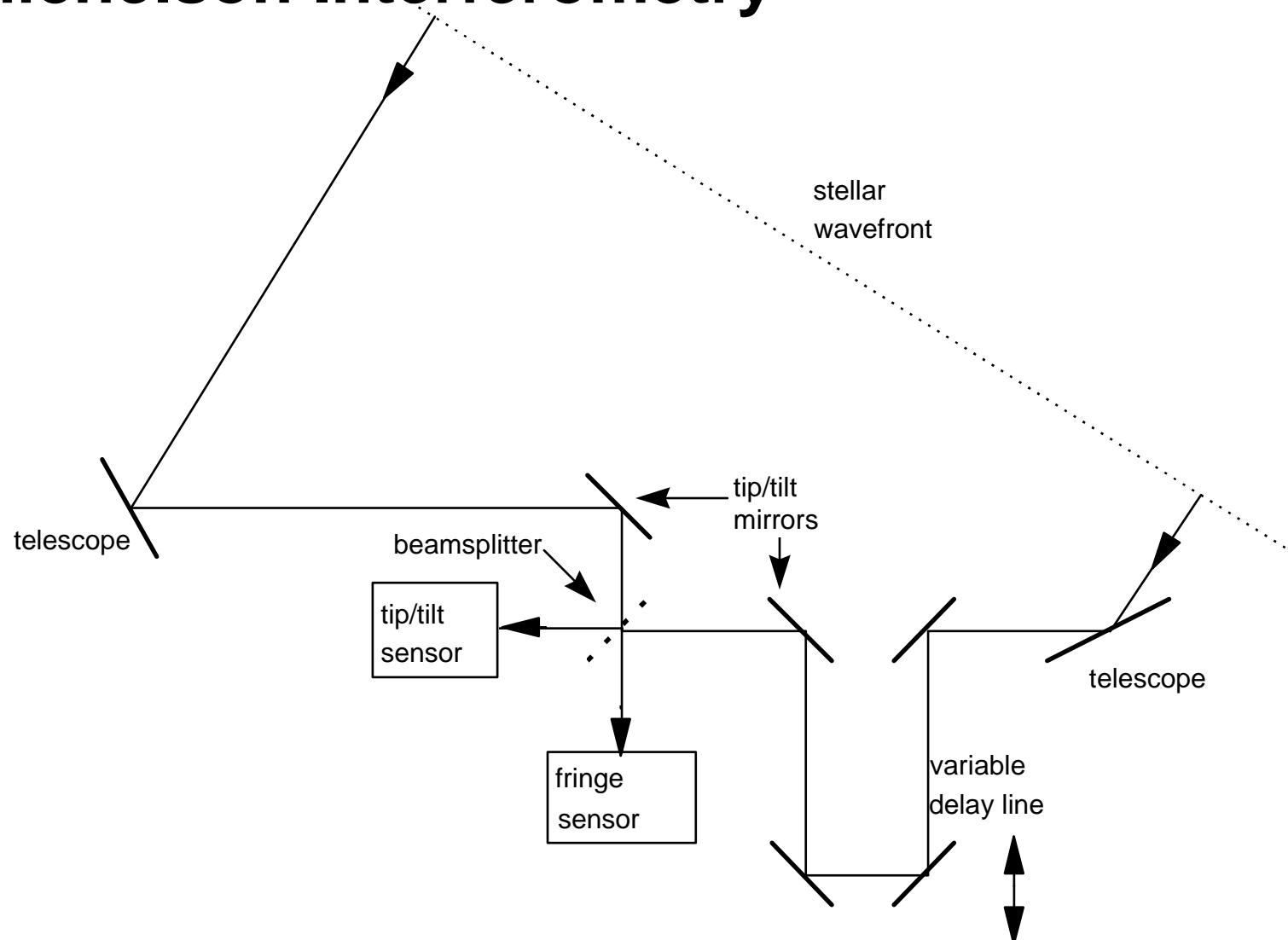
# KECK INTERFEROMETER

## Cophasing / Science Modes to be Supported

TYPE	COPHASING BASELINES	APPLICATION
2-way		zodi, 2-color, faint parametric imaging
2 x 2-way		astrometry
4-way		outrigger-only imaging
5-way		1 Keck + outrigger imaging
6-way		2 Keck + outrigger imaging

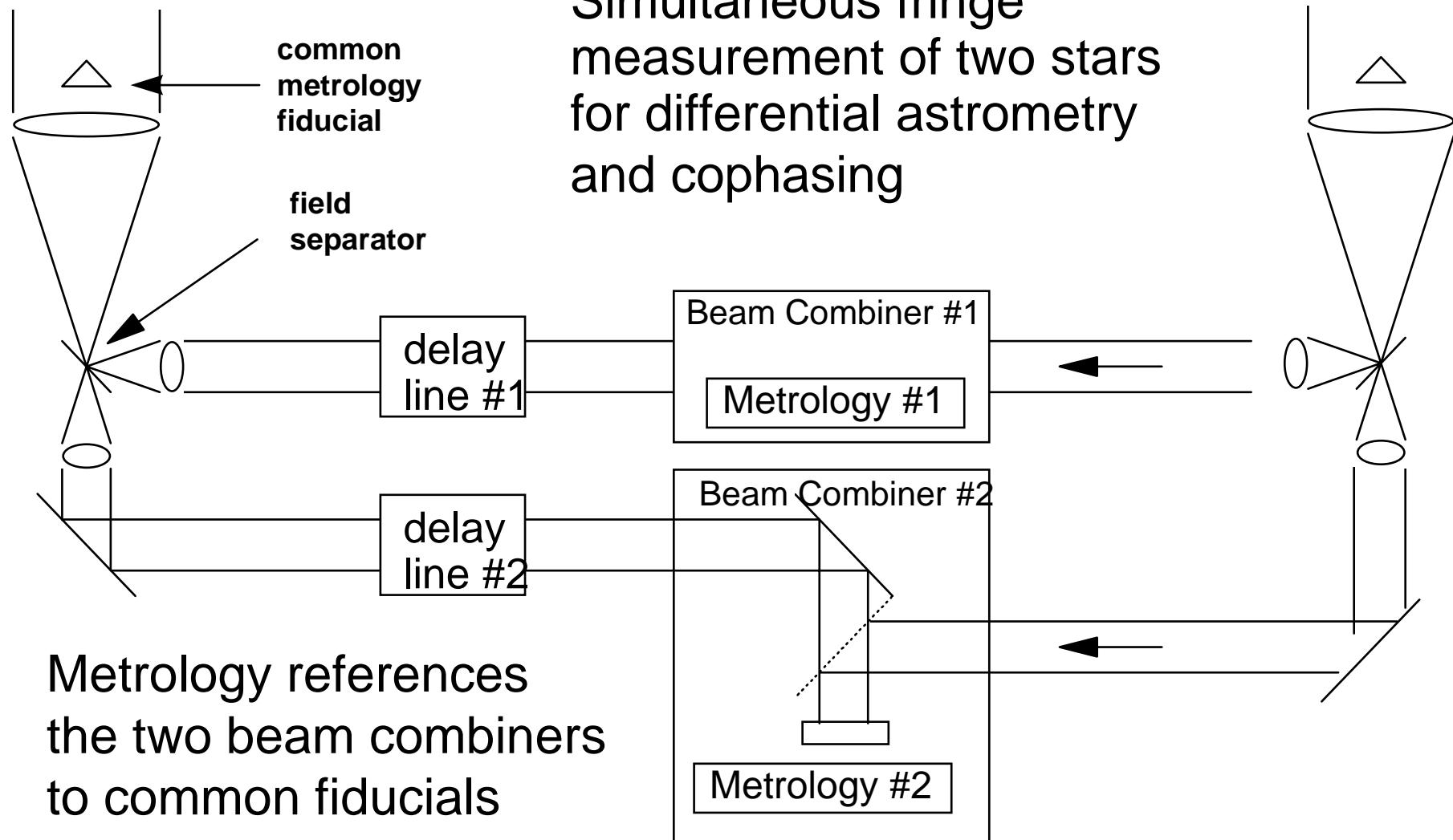
# KECK INTERFEROMETER

## Michelson Interferometry



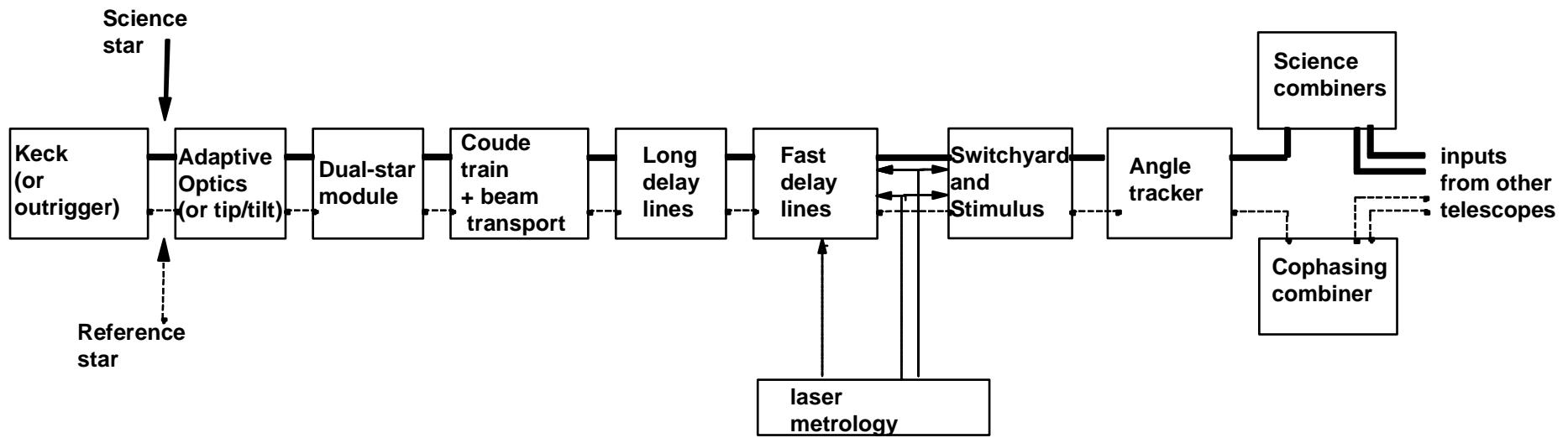
# KECK INTERFEROMETER

## Dual Object Interferometry



# KECK INTERFEROMETER

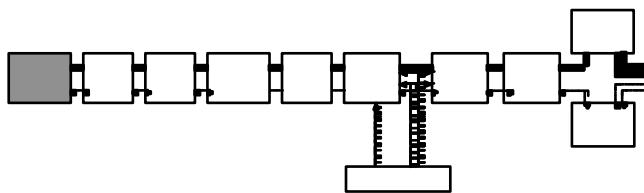
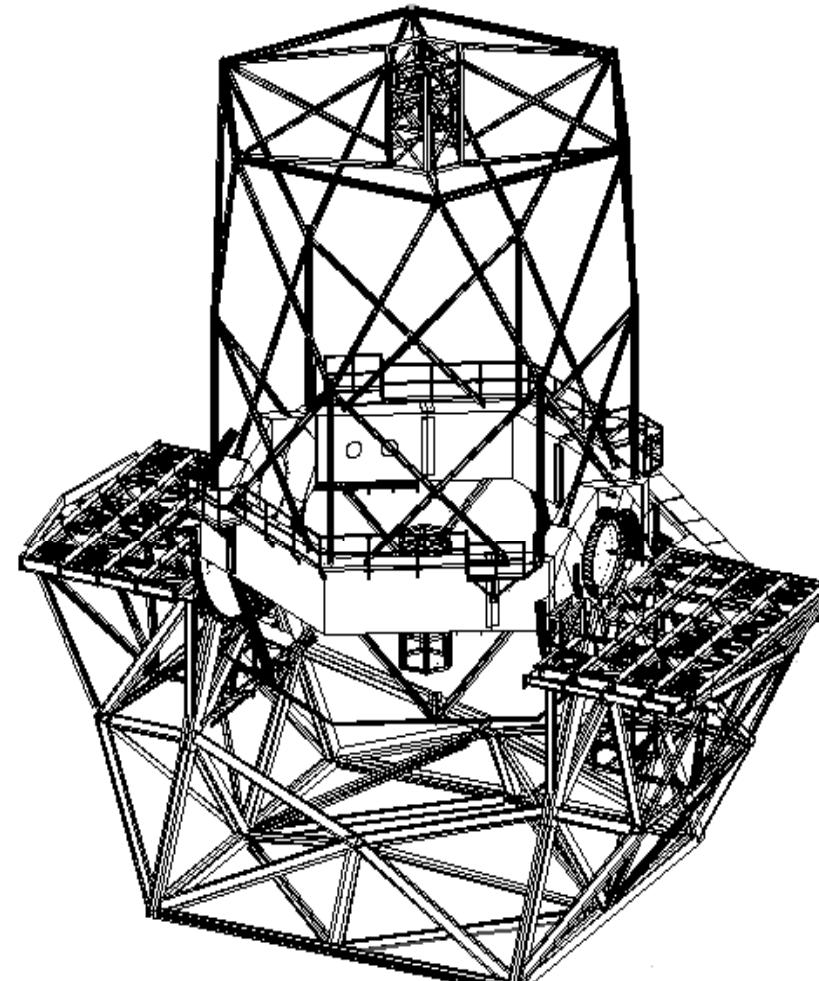
## Keck Interferometer Beam Train



# KECK INTERFEROMETER

## Keck Telescopes

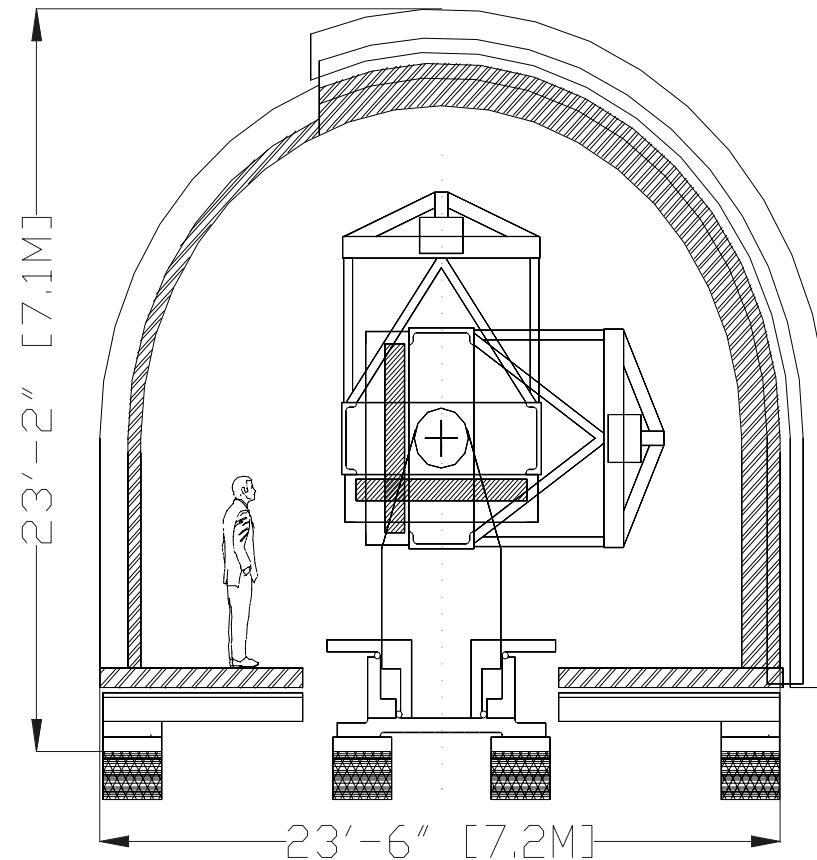
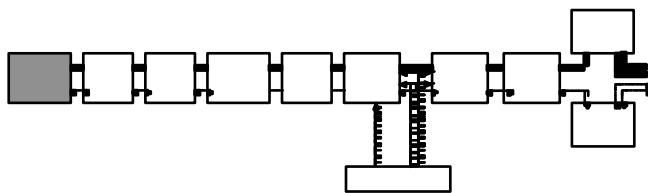
- Both 10-m Kecks are commissioned and producing science



# KECK INTERFEROMETER

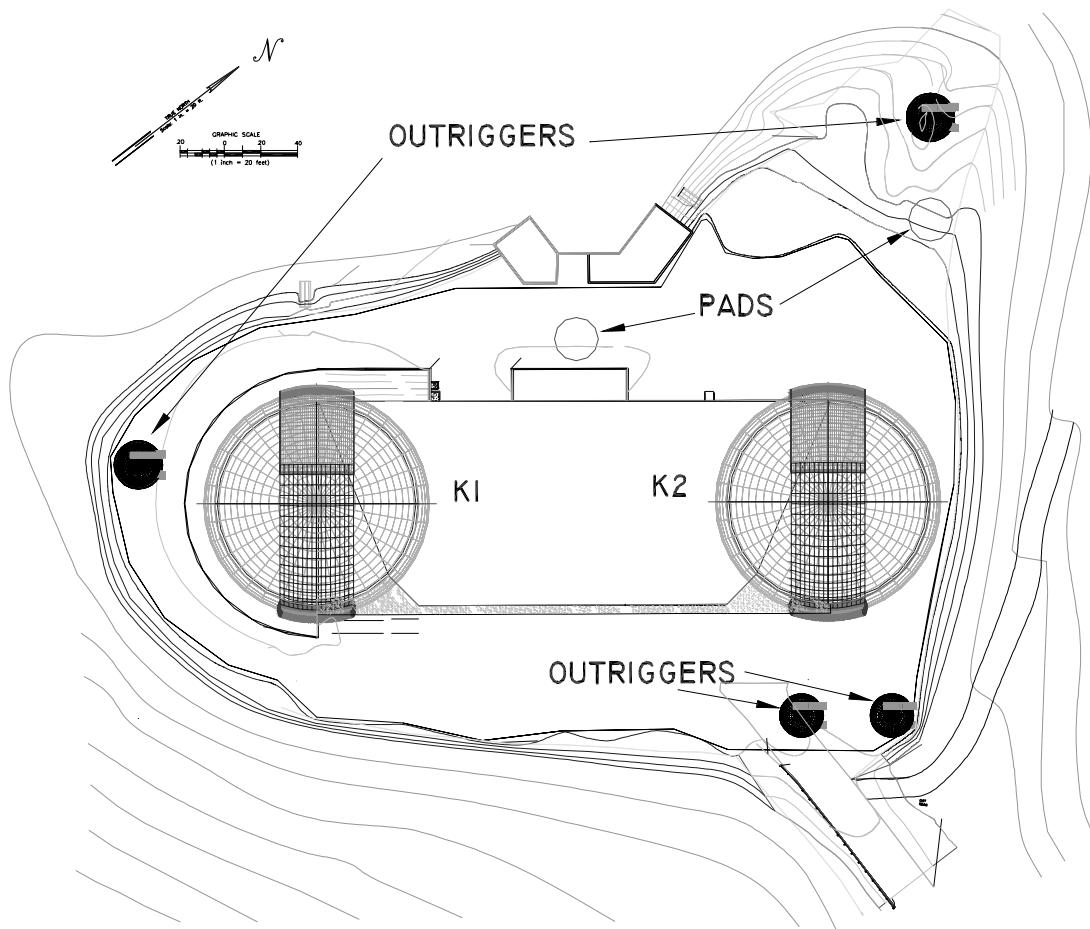
## Outrigger telescopes

- 4 1.8-m coude telescopes for imaging with Kecks and astrometry
- 10-cm collimated output
- Important specifications
  - Atmospheric-limited image quality
  - High throughput
  - Stable pivot for astrometry
- PTI-like siderostats for initial target acquisition



# KECK INTERFEROMETER

## Site Plan View

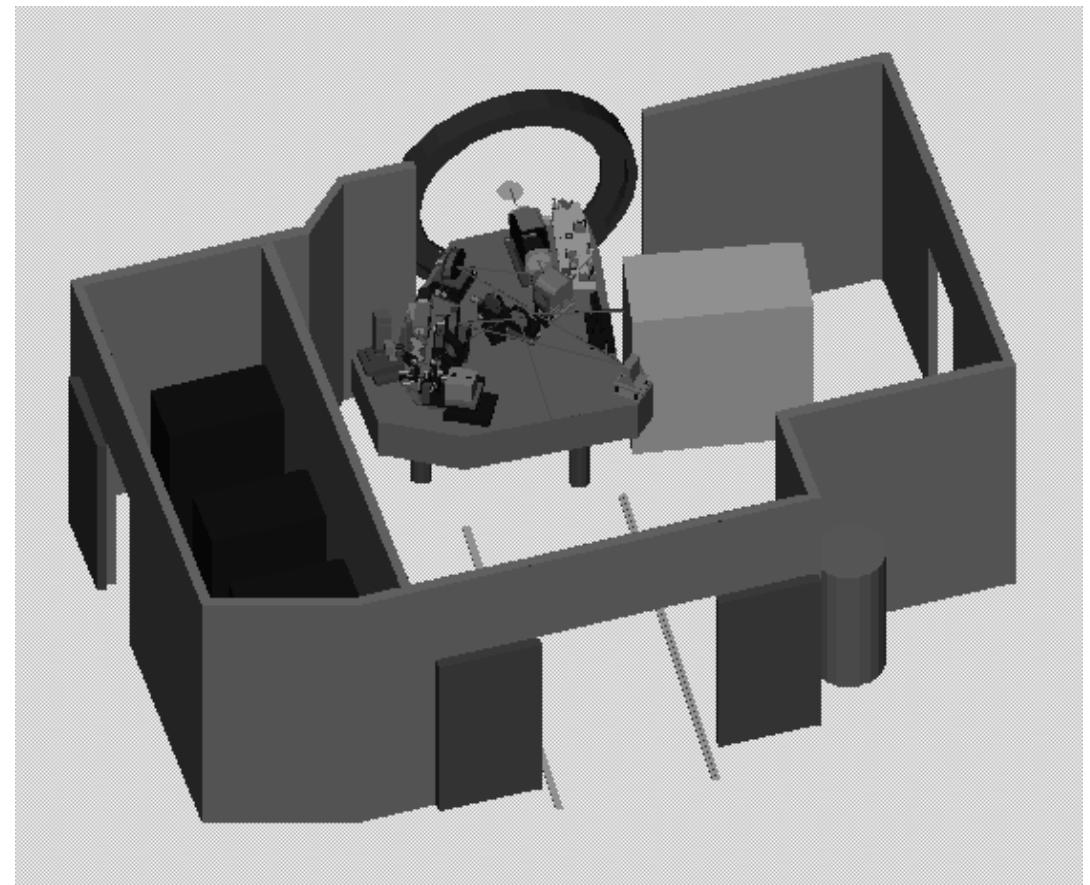
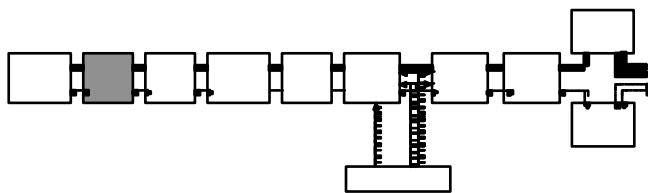


- 4 Outrigger telescopes
- 2 More outrigger pads (for future expansion)
- Underground pipes for light propagation to keck basement
- Junction boxes under outriggers and at corners

# KECK INTERFEROMETER

## Adaptive Optics

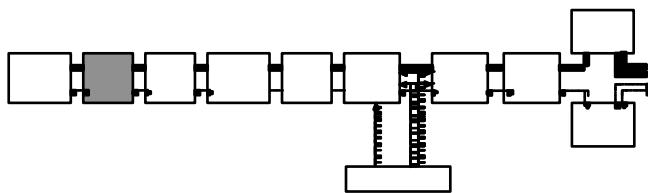
- NGS + LGS AO on K2
- Add new system for K1
- Feeds dual-star module
- Minor mods needed to accommodate interferometry



# KECK INTERFEROMETER

## Tip/Tilt correction

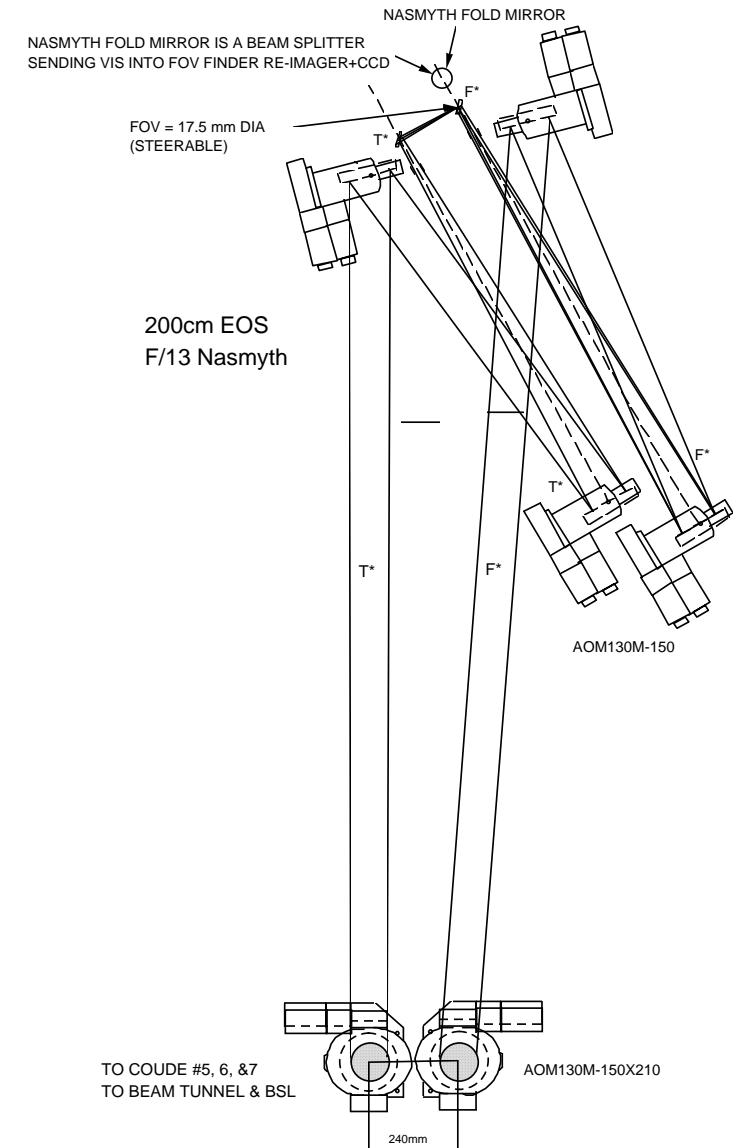
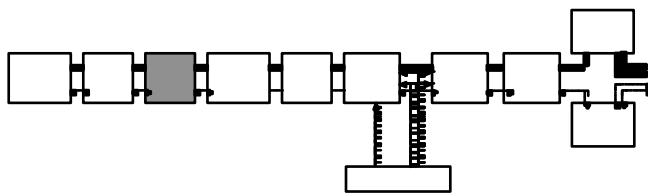
- For outriggers, smaller aperture and infrared operation allow fast tip/tilt correction only
- Sensor will be at end of beam train in interferometer
- Actuator will be active tertiary mirror on outrigger



# KECK INTERFEROMETER

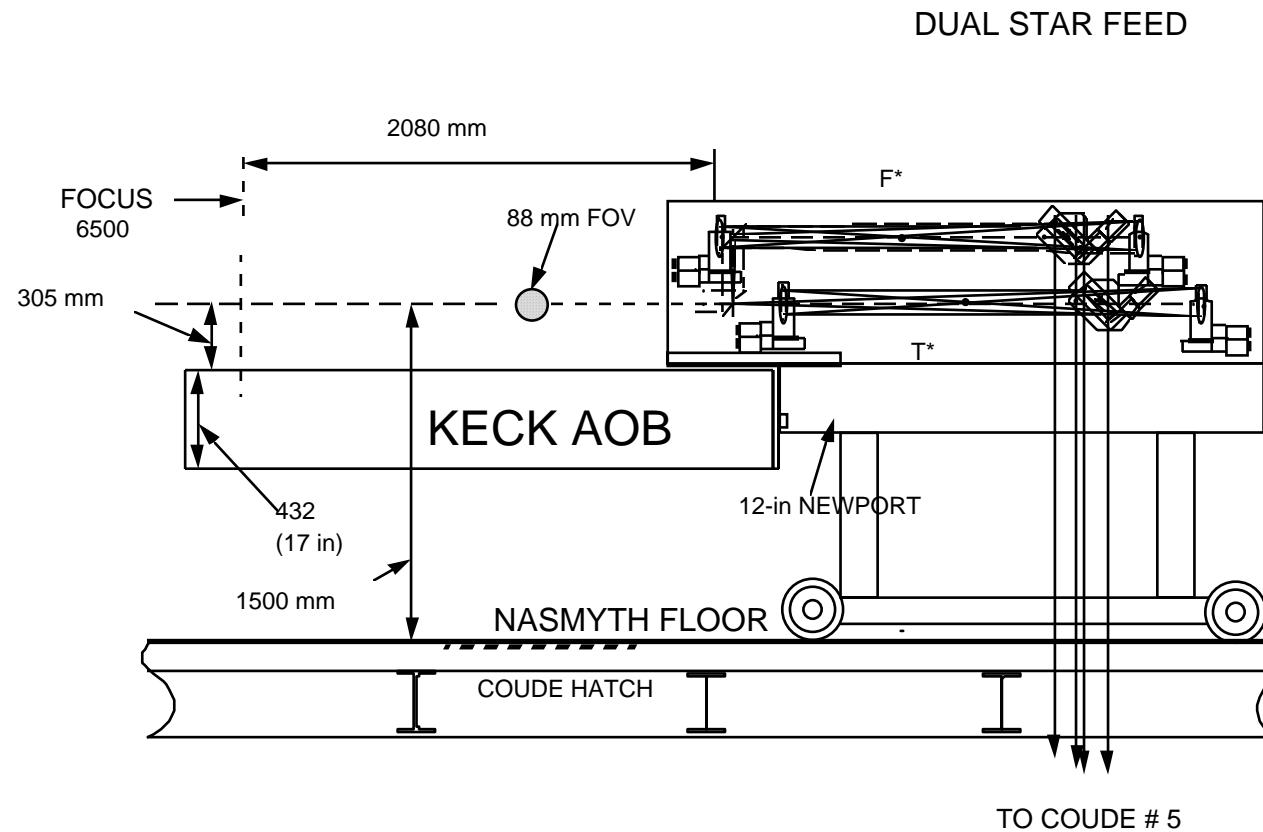
## Dual-star module (DSM)

- Separate and track primary and secondary stars for cophasing and astrometry
- Output two collimated beams to coude train
- DSM for Kecks slides in like NIRSPEC
- DSM for outriggers on Nasmyth or Coude



# KECK INTERFEROMETER

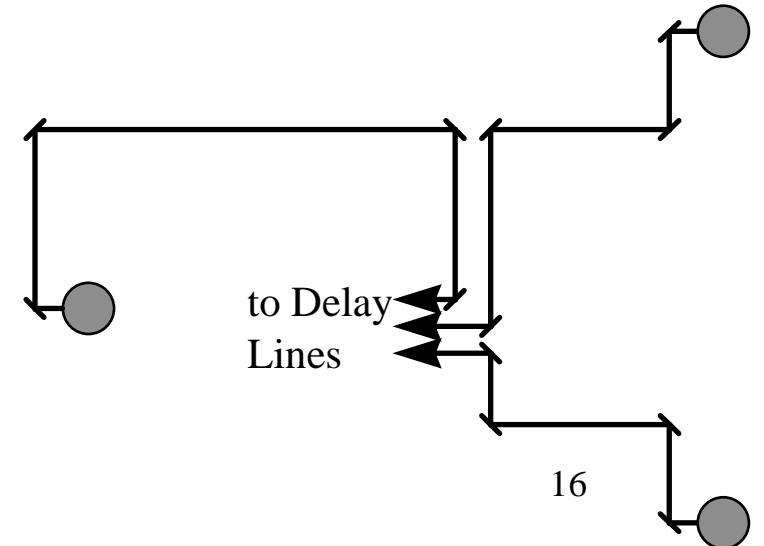
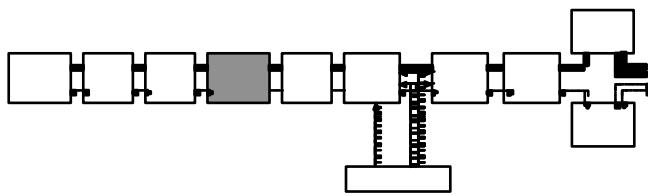
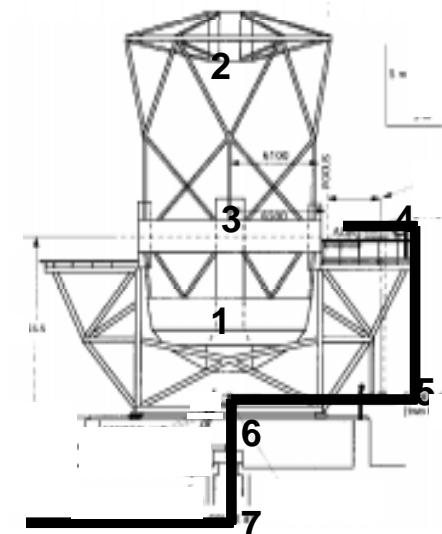
## DSM: Preliminary Design for Keck Nasmyth



# KECK INTERFEROMETER

## Coude Train and Beam Transport

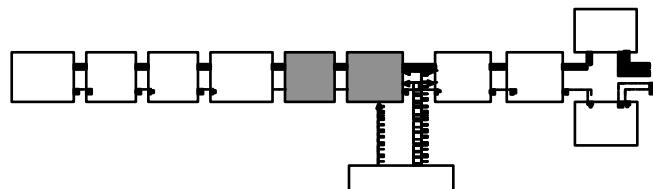
- Keck coude train needs to be completed to bring light from DSM to base of telescope (M7)
  - Also need to derotate secondary beam
- Similar coude needed on outriggers
- Beam transport system routes light from M7 to delay lines in interferometry lab



# KECK INTERFEROMETER

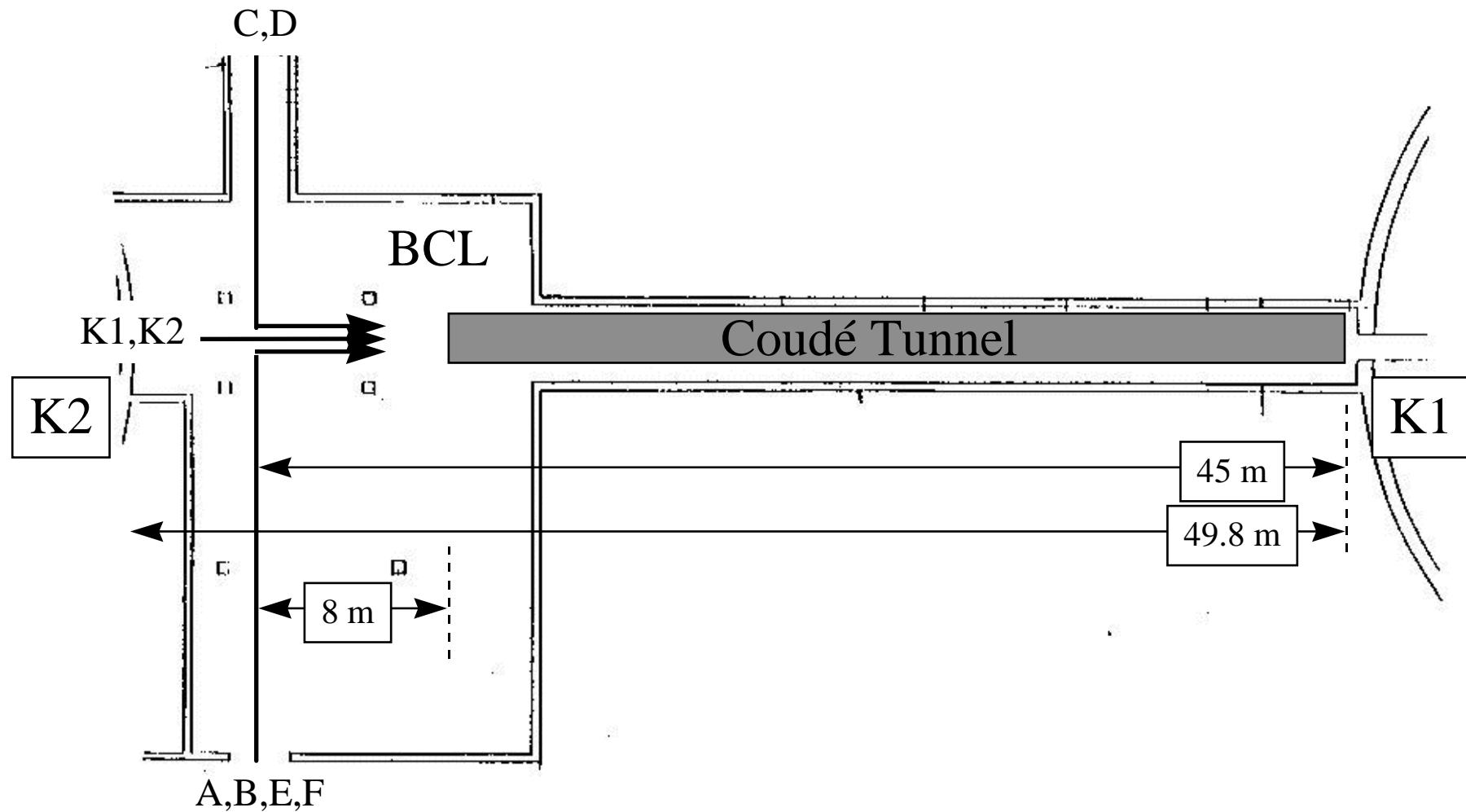
## Delay Lines

- Two systems
  - Long delay line
    - » Move and clamp system in coude tunnel
  - Fast delay line
    - » Sidereal and fringe tracking in optics lab



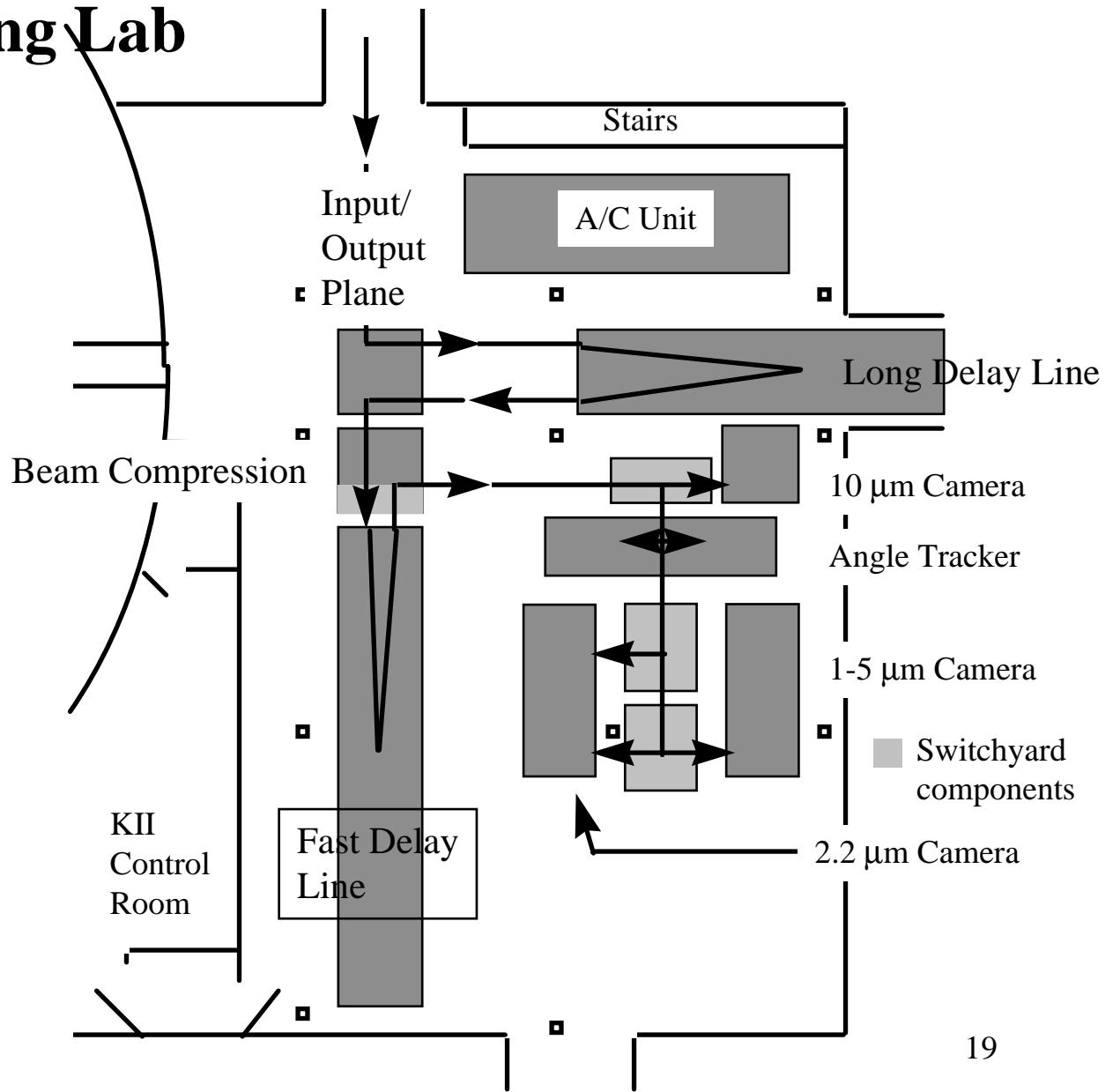
# KECK INTERFEROMETER

## Long Delay Line : Location



# KECK INTERFEROMETER

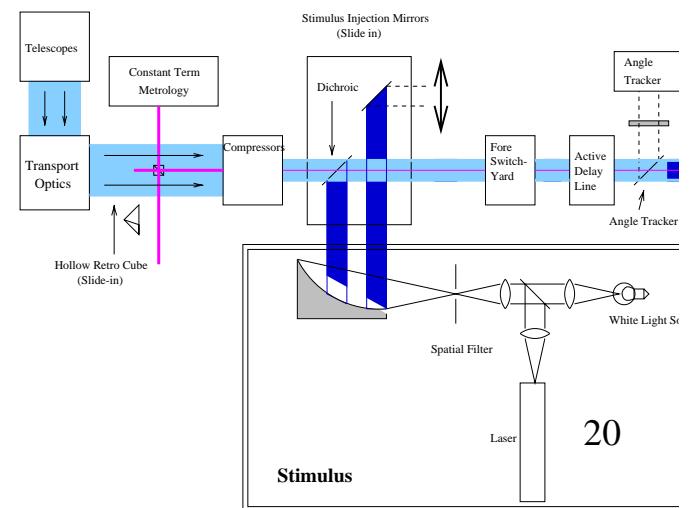
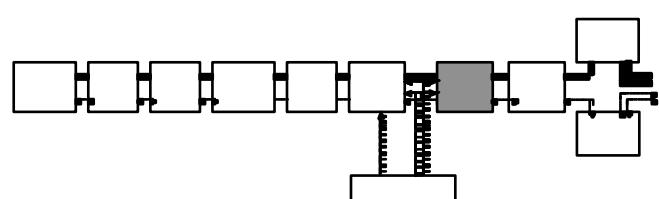
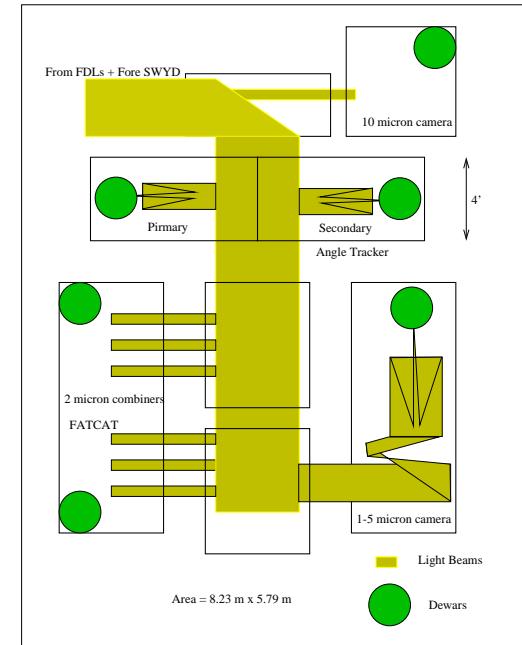
## Beam Combining Lab



# KECK INTERFEROMETER

## Switchyard and stimulus

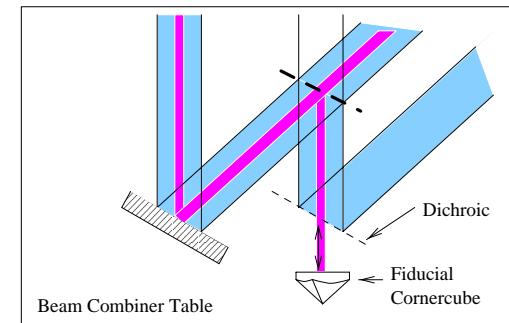
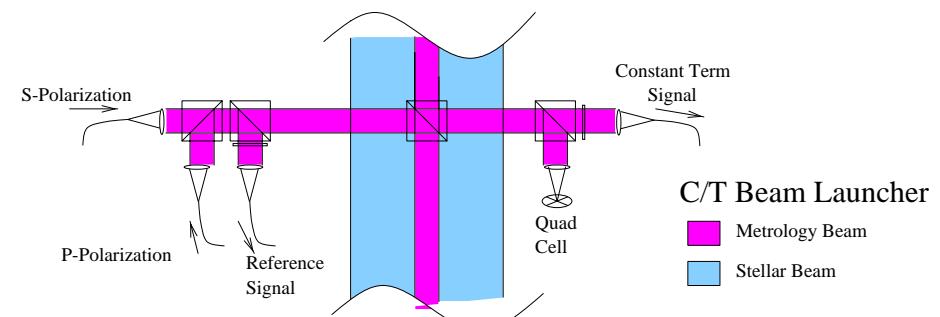
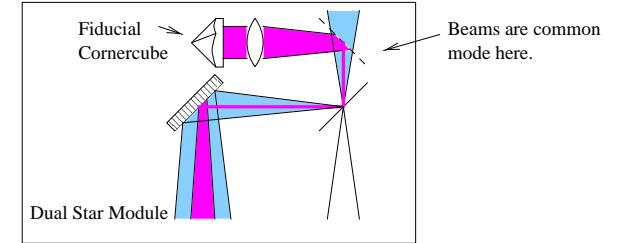
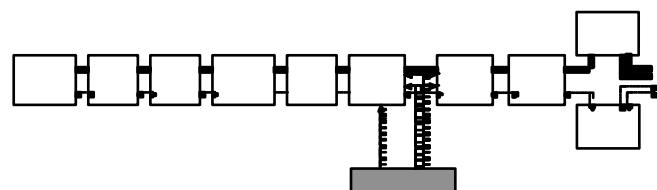
- Switchyard: accept 12 delayed starlight beams and direct to beam combiner for desired mode
- Stimulus: star simulator to test all starlight subsystems



# KECK INTERFEROMETER

## Laser Metrology

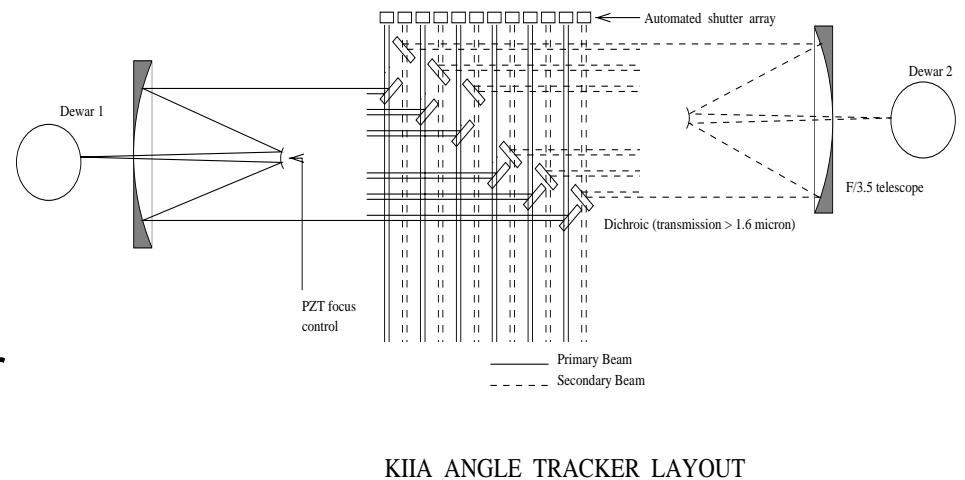
- Three types
  - Local metrology of delay lines for servo control
  - End-to-end metrology of optical path for astrometry and cophasing
  - Accelerometer sensing of common-mode telescope optics



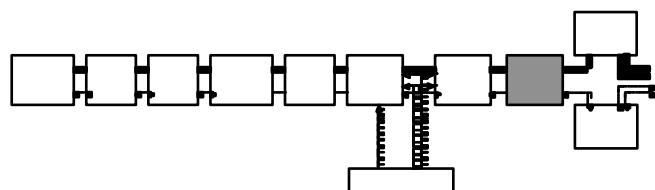
# KECK INTERFEROMETER

## Angle tracker

- For Outriggers:
  - Fast primary star tracking
  - Slow secondary star tracking
- For Kecks:
  - Track offsets to AO system
- Implementation
  - J-band sensing in interferometer
  - Tip/Tilt mirror for outrigger
  - Feedback to AO system for Keck



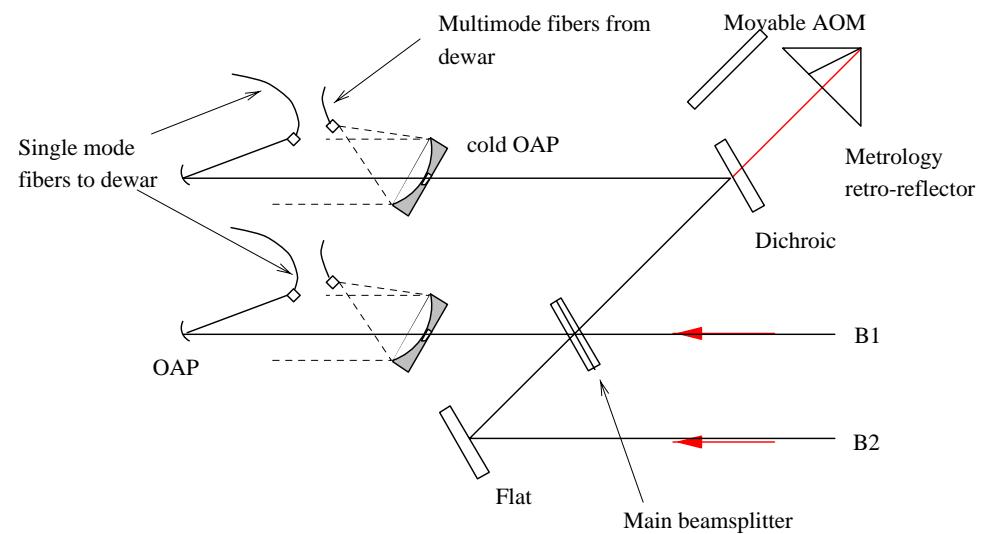
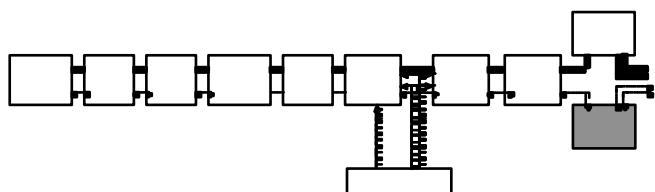
KIIA ANGLE TRACKER LAYOUT



# KECK INTERFEROMETER

## Cophasing (2 um) combiner

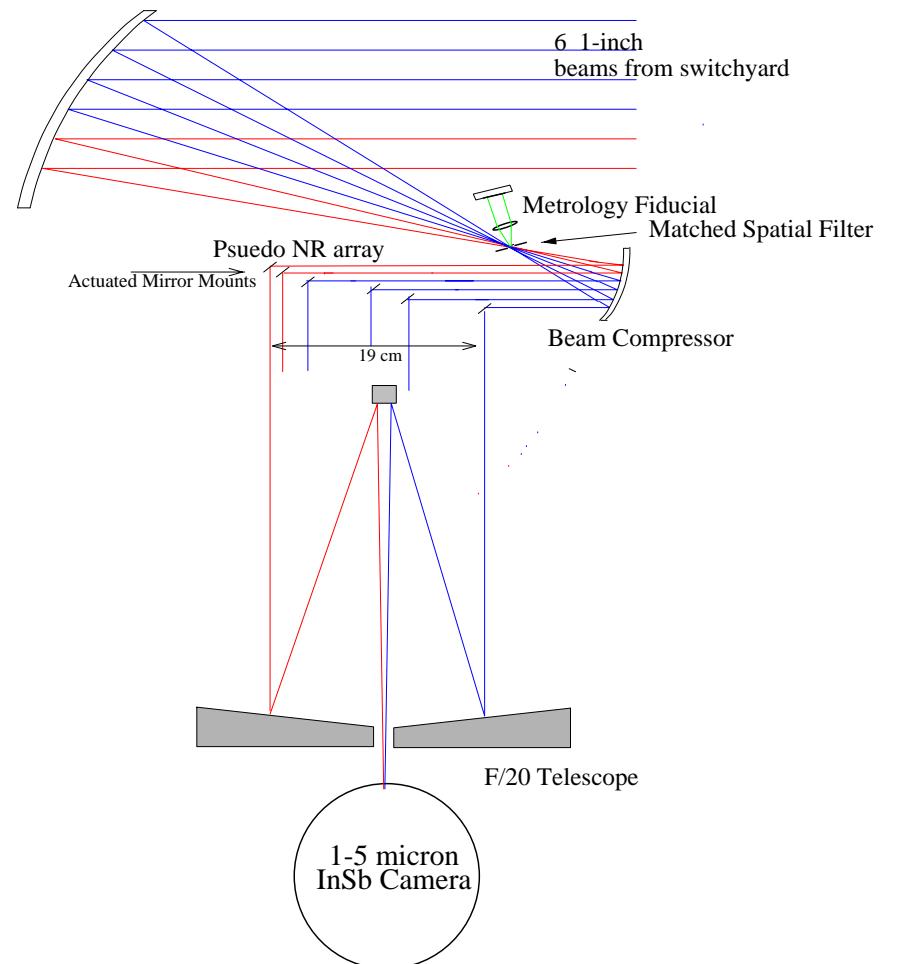
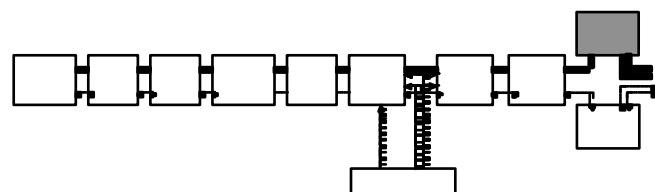
- Provide 5 two-way 2-um combiners to support
  - Cophasing at H&K
  - Astrometry primary
  - Astrometry secondary
  - Single-baseline science
- Use low-noise FPA with fast readout capability like PTI



# KECK INTERFEROMETER

## Multi-way science combiner concept

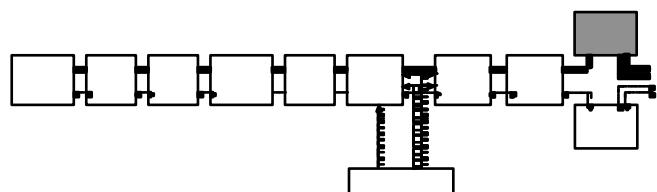
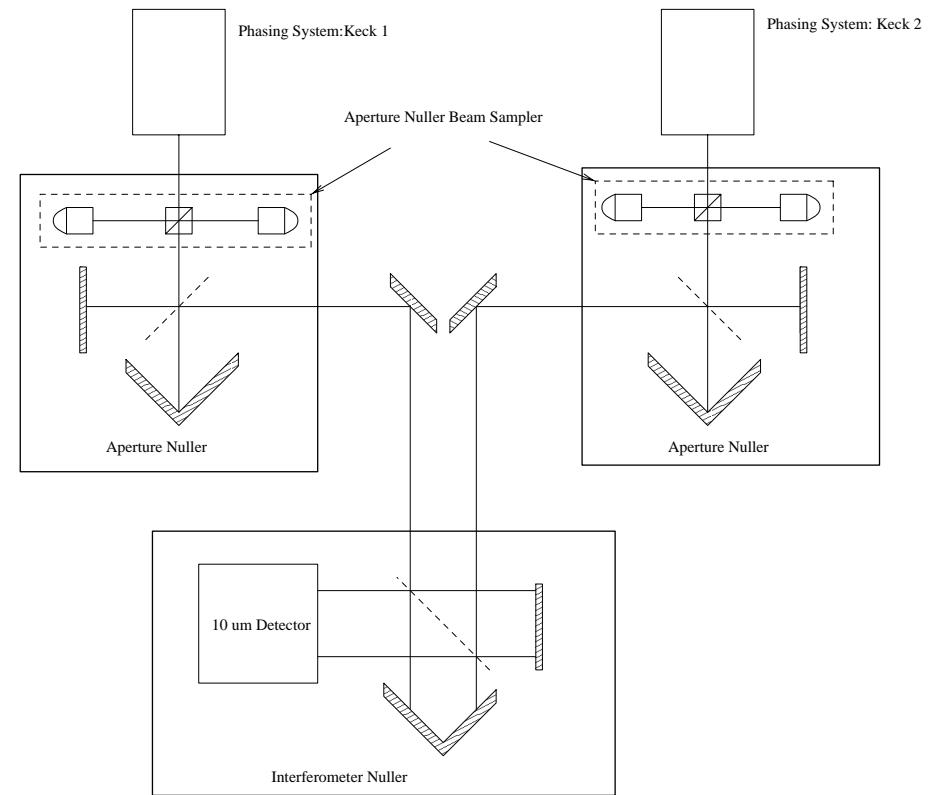
- Pair-wise measurements on up to 15 baseline simultaneously
- Non-redundant cross-dispersed image-plane combiner
- 1.6-5.0 micron coverage with InSb array
- 10 um coverage with 10-um nulling camera



# KECK INTERFEROMETER

## 10 um Nulling combiner

- Primary instrument for exozodiacal characterization
- Fast, switchable nulls on two spatial scales
  - Interferometer nullder
    - » Nulls out central star
  - Aperture nullder
    - » Nulls out zodi + star
- Uses procured 10-um FPA camera



# KECK INTERFEROMETER

## Real-time control system

- Control distributed system
- Interface to Keck, Outrigger, and AO system
- Approach
  - Use Palomar-like multiprocessing system
  - Use common core electronics and software being developed by JPL Realtime Interferometer Control System Testbed
  - Develop additional Keck-specific modules and functionality
  - Use off-the-shelf components wherever possible
  - EPICS to interface with Keck systems
  - Good maintainability, documentation, and adherence to software standards

# KECK INTERFEROMETER

## Expected Performance (NGS)

On-axis Full Array Cophasing Limit:	4 Outriggers		1 Keck + 4 Outriggers		2 Kecks + 4 Outriggers		
	2m / 2m	10m / 2m	2m / 2m	10m / 10m	10m / 2m	2m / 2m	
2.2 um		11.0	12.8	N/A	15.0	12.9	N/A
Off-axis Limit:	Astrometric	4 Outriggers	1 Keck + 4 Outriggers		2 Kecks + 4 Outriggers		
	2m / 2m	2m / 2m	10m / 2m	2m / 2m	10m / 10m	10m / 2m	2m / 2m
1.6 um	N/A	19.1	21.2	19.0	23.5	21.0	18.8
2.2 um	17.0	18.2	20.1	18.0	22.1	20.0	17.9
3.5 um	N/A	13.5	15.3	13.3	17.1	15.1	13.2
5 um	N/A	11.0	12.7	10.8	14.5	12.6	10.7
10 um	N/A	7.5	9.2	7.3	10.9	9.1	7.2

**SNR=10 for cophasing, K only**

**SNR=10 per baseline in 1000 sec for imaging**

**SNR=72 in 3600 sec for astrometry**